

Claims

1. A power system for transferring power between a plurality of power sources comprising:
 - a first power source having a first pair of terminals associated therewith;
 - 5 a second power source having a second pair of terminals associated therewith;
 - a third power source having a third pair of terminals associated therewith; and
 - 10 a power converter including,
 - (i) a first pair of switches connected to the first pair of terminals, said first switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a first common node, and wherein each of the first pair of switches has an anti-parallel diode associated therewith;
 - (ii) 15 a second pair of switches connected to the second pair of terminals, said second switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a second common node, and wherein each of the second pair of switches has an anti-parallel diode associated therewith;
 - (iii) 20 a third pair of switches connected to the third pair of terminals, said third switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a third common node, and wherein each of the third pair of switches has an anti-parallel diode associated therewith;
 - (iv) 25 a first inductor connected between the first common node and the second common node;
 - (v) 30 a second inductor connected between the first common node and the third common node; and
 - (vi) a control unit configured to actuate the switches in the first, second, and third pairs of switches in accordance with one of a plurality of modes of

35 operation for transferring power between at least a pair of said first, second, and third power sources.

2. A power system according to claim 1 wherein the first power source is a DC Link which derives from a fuel cell whose output is electrically connected to the input of a power conditioner, the second power source is a battery, and the third power source is an ultracapacitor; and wherein said plurality of modes of operation include:

5 a battery-to-DC Link boost mode;
a battery-to-ultracapacitor boost mode;
an ultracapacitor-to-DC Link boost mode;
a DC Link-to-battery buck mode;
a DC Link-to-Ultracapacitor buck mode; and
10 a battery-to-ultracapacitor buck mode.

3. A power system according to claim 2 further comprising an application electrically connected to the output of the power conditioner.

4. A power system according to claim 3 wherein said application further includes an inverter and a load connected to said inverter.

5. A power system according to claim 1 wherein the power converter switches of the first, second, and third pairs of switches are of the MOSFET type.

6. A power system according to claim 1 wherein the power converter switches of the first, second, and third pairs of switches are of the IGBT type.

7. A power system according to claim 1 wherein the power converter control unit is configured to control ON/OFF conduction states of the switches to define a respective switch arrangement corresponding to each one of the plurality of modes of operation, the control unit being further configured to establish a sequence of switch arrangements during corresponding time intervals for each one of the plurality of modes of operation.

8. A power system for transferring power between a plurality of power sources comprising:

5 a first power source having a first pair of terminals associated therewith;

10 a second power source having a second pair of terminals associated therewith;

15 a third power source having a third pair of terminals associated therewith; and

a power converter including,

20 (i) a first pair of switches connected to the first pair of terminals, said first switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a first common node, and wherein each of the first pair of switches has an anti-parallel diode associated therewith;

25 (ii) a second pair of switches connected to the second pair of terminals, said second switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a second common node, and wherein each of the second pair of switches has an anti-parallel diode associated therewith;

30 (iii) a third pair of switches connected to the third pair of terminals, said third switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a third common node, and wherein each of the third pair of switches has an anti-parallel diode associated therewith;

(iv) a first inductor connected between the first common node and the second common node;

35 (v) a second inductor connected between the first common node and the third common node; and

(vi) a control unit configured to actuate the switches in the first, second, and third pairs of switches in accordance with one of a plurality of modes of

35 operation for transferring power between at least a pair of said first, second, and third power
sources; wherein said plurality of modes of operation include:

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- a battery-to-DC Link boost mode;
- a battery-to-ultracapacitor boost mode;
- an ultracapacitor-to-DC Link boost mode;
- a DC Link-to-battery buck mode;
- a DC Link-to-Ultracapacitor buck mode; and
- a battery-to-ultracapacitor buck mode.

9. A power system according to claim 8 wherein the first power source is a DC Link which derives from a fuel cell whose output is electrically connected to the input of a power conditioner, the second power source is a battery, and the third power source is an ultracapacitor

10. A power system according to claim 9 further comprising an application electrically connected to the output of the power conditioner.

11. A power system according to claim 10 wherein said application further includes an inverter and a load connected to said inverter.

12. A power system according to claim 8 wherein the power converter switches of the first, second, and third pairs of switches are of the MOSFET type.

13. A power system according to claim 8 wherein the power converter switches of the first, second, and third pairs of switches are of the IGBT type.

14. A power system according to claim 8 wherein the power converter control unit is configured to control ON/OFF conduction states of the switches to define a respective switch arrangement corresponding to each one of the plurality of modes of operation, the control unit being further configured to establish a sequence of switch arrangements during corresponding time intervals for each one of the plurality of modes of operation.

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15. A power system for transferring power between a plurality of power sources comprising:

5 a first power source having a first pair of terminals associated therewith, wherein the first power source is a DC Link which derives from a fuel cell whose output is electrically connected to the input of a power conditioner;

10 a second power source having a second pair of terminals associated therewith, wherein the second power source is a battery;

a third power source having a third pair of terminals associated therewith, wherein the third power source is an ultracapacitor; and

15 a power converter including,

15 (i) a first pair of switches connected to the first pair of terminals, said first switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a first common node, and wherein each of the first pair of switches has an anti-parallel diode associated therewith;

20 (ii) a second pair of switches connected to the second pair of terminals, said second switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a second common node, and wherein each of the second pair of switches has an anti-parallel diode associated therewith;

25 (iii) a third pair of switches connected to the third pair of terminals, said third switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a third common node, and wherein each of the third pair of switches has an anti-parallel diode associated therewith;

30 (iv) a first inductor connected between the first common node and the second common node;

(v) a second inductor connected between the first common node and the third common node; and

(vi) a control unit configured to actuate the switches in the first, second, and third pairs of switches in accordance with one of a plurality of modes of

35 operation for transferring power between at least a pair of said first, second, and third power sources.

16. A power system according to claim 15 wherein the plurality of modes of operation include:

- a battery-to-DC Link boost mode;
- a battery-to-ultracapacitor boost mode;
- 5 an ultracapacitor-to-DC Link boost mode;
- a DC Link-to-battery buck mode;
- a DC Link-to-Ultracapacitor buck mode; and
- a battery-to-ultracapacitor buck mode.

17. A power system according to claim 15 further comprising an application electrically connected to the output of the power conditioner.

18. A power system according to claim 17 wherein said application further includes an inverter and a load connected to said inverter.

19. A power system according to claim 15 wherein the power converter switches of the first, second, and third pairs of switches are of the MOSFET type.

20. A power system according to claim 15 wherein the power converter switches of the first, second, and third pairs of switches are of the IGBT type.

21. A power system according to claim 15 wherein the power converter control unit is configured to control ON/OFF states of the switches to define a respective switch arrangement corresponding to each one of the plurality of modes of operation, the control unit being further configured to establish a sequence of switch arrangements during 5 corresponding time intervals for each one of the plurality of modes of operation.